HADRONIC JOURNAL 47, 89 - 94 (2024)
DOI 10.29083/HJ.47.01.2024/SC89

INTERPRETATION OF THE MECHANISM OF THE INFLUENCE OF π^0 – MESONS ON THE PROCESS OF ATTRACTION OF NUCLEI

Mikhail Kashchenko
Ural Federal University, Ekaterinburg, Russia
Ural State Forestry University, Ekaterinburg, Russia
mpk46@mail.ru
and
Nadezhda Kashchenko
Ural Federal University,
Ekaterinburg, Russia

Received December 28, 2023

Abstract

There are two stages in the process of low-temperature nuclear fusion. The first stage corresponds to the bringing together of nuclei due to attraction to the negative charge in the internuclear space. This charge is formed by massive electron pairs located in a circular orbit. According to hadronic mechanics, the attraction of electrons (with opposite spins) is ensured by contact interaction. The second stage corresponds to the exchange of nuclei by pions, which begins when the nuclei approach each other to a distance equal to the strong interaction radius R_s. To estimate the maximum value of R_S^*, the concepts of hadron mechanics about the π^0 - meson as a bound electron - positron ($e^- e^+$) - pair are used. The main attention is paid to the visual interpretation of the electromagnetic interaction ($e^- e^+$) - pairs with nuclei, promoting the attraction of nuclei.

Key words: low-temperature fusion of nuclei, contact interaction of electrons, strong interaction, pions, electron-positron pairs.

Introduction

Currently, there is a lot of experimental evidence of low-temperature nuclear fusion, ranging from the simplest reactions of muon catalysis to the fusion of complex nuclei. As noted in [1], the synthesis of nuclei when a proton is captured by nuclei with charge numbers an orders of magnitude greater than unity, and, moreover, fusion reactions of complex nuclei at low temperatures should not occur due to tunneling. Such a synthesis requires bringing nuclei closer to distances at which the strong interaction of attraction between nuclei begins to exceed the Coulomb repulsion. Let us introduce the notation R_s for the strong interaction radius. Obviously, the larger the value of R_s, the faster the convergence of nuclei required for the fusion reaction can be achieved.

It is known that the strong interaction is short-range, i.e. R_s is orders of magnitude smaller than the atomic scale $R_a \sim 10^{-10}$ m. Therefore, the "switching on" of the strong interaction must be preceded by the process of bringing nuclei together from R_a to $2d \leq R_s$, where d is half the internuclear distance. According to the authors, this preliminary process is described relatively simply in the intermediate quasi- molecular state (IQS) model. The IQS diagram is shown in Fig. 1.

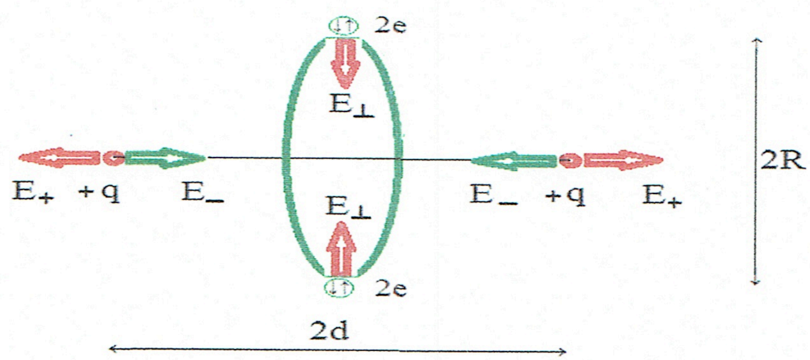

Fig.1. Scheme of the simplest model of a IQS in a state of electrostatic equilibrium (the R/d ratio is reduced compared to the calculated value √3, the CC activator contains two electron pairs)

In this model, according to [1-4], the approach of nuclei is achieved due to the attraction of nuclei with a charge +q to a massive negative charge in the internuclear space. The negative charge is associated with a configuration in the form of compact massive electron pairs located in a circular orbit. This object, which catalyzes nuclear fusion, is called, for brevity, a CC activator. Pairs of electrons have opposite spins and are connected by an attractive contact interaction that dominates Coulomb repulsion. Nonpotential contact interaction is described by hadronic mechanics [5].

Estimation of the maximum value of the strong interaction radius

We believe that the conditions for the first stage of nuclear convergence in the IQS model are met. Let us then show, following [1], that for the value of R_s we can use the estimate $R_s \approx 100$ fm.

Let us recall that the mechanism of any type of interaction of objects that are not in contact with each other in quantum field theory is reduced to the exchange of virtual particles - the carriers of this interaction. In the case of strong internuclear interaction of interest to us, the mechanism first proposed by Yukawa [6] remains relevant. In this case, nucleons exchange virtual π - mesons, just as electric charges exchange virtual photons.

Let us also recall that of the three π^0, π^+, π^- - mesons, the π^0 - meson has the smallest rest mass (≈ 135 MeV on the energy scale). Consequently, the estimate of the maximum value of the radius $(R_s)_{max}$ that interests us is associated with the exchange of nucleons by π^0 - mesons. The standard estimate of the interaction radius in quantum mechanics is given by

$$R \approx c\,\Delta t \approx \hbar c / 2\Delta E, \qquad (1)$$

where $c \approx 3\ 10^{8}$ m/s and $\hbar = h/2\,\pi \approx 1.05 \cdot 10^{-34}$ J s and it is taken into account that the uncertainties in energy ΔE and time Δt are related by the Heisenberg relation

$$\Delta E\ \Delta t \geq \hbar/2. \qquad (2)$$

It is clear that at finite interaction radii, the maximum value of R corresponds to the minimum value ΔE of the order of the rest energy of the virtual particle, if it is neutral (π^0 - the meson is neutral). If virtual particles have an electric charge, then, in accordance with the law of conservation of electric charge, they should be born in pairs, so that the exchange of nucleons by π^+, π^- - mesons is associated with a smaller radius R_s compared to R_s when exchanging π^0 - mesons.

Moreover, if we assume that, according to hadronic mechanics [5], the π^0 - meson is a bound state of an electron and a positron, then as the maximum value of R_s we can formally take the value $R_S^* \approx 10^{-13}$ m. Indeed, the energy spectrum of the electron is positron pairs (associated with the π^0 - meson) lies in the range ≈ (1 - 135) MeV, that is, it is limited from below by the value of the positronium rest energy. Therefore, we take $\Delta E \approx 1.022$ MeV as the minimum value. Then from (1) we obtain $R_S^* \approx 100$ fm = 10^{-13} m. Note that the values of R_S^* and the Compton electron wavelength are of the same order of magnitude. This indicates a characteristic intermediate scale (between the atomic and hadron scales).

"Flickering mode" of the action of (e^-e^+)-pairs on nuclei

Let us recall that the classical model of positronium represents a pair of oppositely charged point particles (with masses equal to the rest mass of an electron) rotating in a circular orbit around a common center of inertia. In this case, the radius of the positronium orbit is approximately twice the Bohr radius, that is,

it has an atomic scale. Then a reasonable question arises: is it possible to compare the formal estimate of R_S^* with an acceptable visual picture of the interaction of nuclei with the participation of positronium? Indeed, for nucleons located at distances d~R_S^* the "exchange" by positronium, the size of which is of the order of $R_a >> R_S^*$, looks, to put it mildly, unconvincing.

Nevertheless, since electromagnetic interaction dominates on the atomic scale, a completely natural and intuitive scenario can be proposed. Namely, we assume that under the conditions of the existence of IQS, the birth of electron-positron (e^-e^+) - pairs from the physical vacuum occurs predominantly with the localization of electrons in the central region of the CC activator. It is clear that such electron localization promotes the approach of nuclei not only due to their attraction to the electron, but also due to repulsion from the positron, whose orbit covers the region containing the nuclei. Of course, under the conditions of the existence of the IQS, the shape of the positron's orbit will differ from a circle. However, when viewed qualitatively, the shape of the orbit does not play a role.

Note that for massive nuclei, the action of the electric field from a fast-moving positron can effectively manifest itself as a "flickering mode" that promotes the approach of one or the other nucleus, as illustrated by the diagram in Fig. 2.

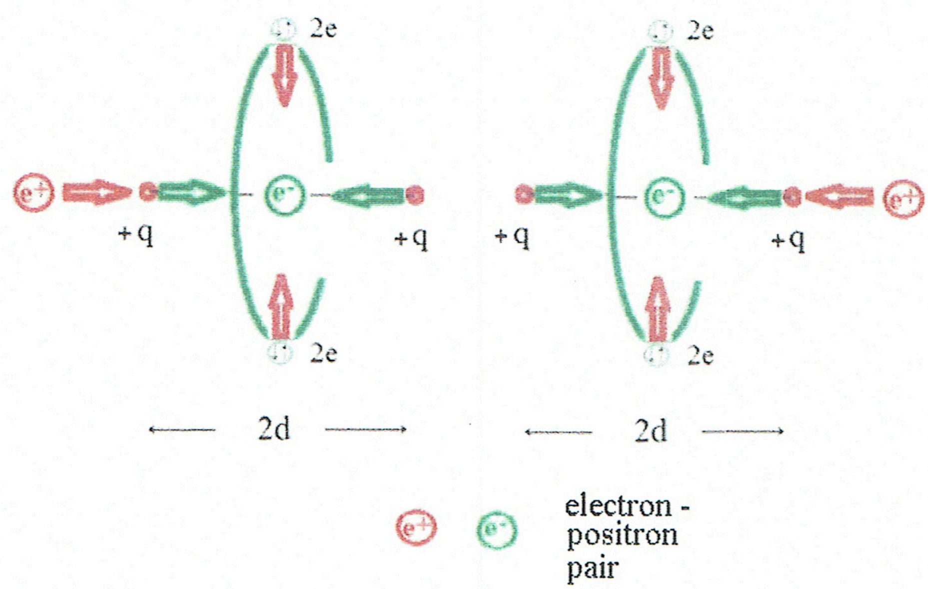

Fig. 2. "Flickering mode" of the action of (e^-e^+)-pairs on nuclei.

Let's give an explanation. Rotation along a circular (or elliptical) orbit is uniquely associated with a pair of oscillations along orthogonal axes. The "flickering mode" can be interpreted as a consequence of the obvious axial symmetry under IQS conditions, which allows one to give preference to one of the vibrations, namely, vibration along the axis of symmetry passing through the nuclei. Indeed, in the presence of an axis of symmetry, the orbits of positrons that enclose nuclei and differ in the orientations of the orbital planes are equally probable. As a result, massive nuclei respond only to the axial component of the electric field of rapidly moving positrons, while the transverse component of the field (due to the rapid change in directions when the orbital plane rotates) is averaged.

It is clear that at a high frequency of appearance and disappearance (e^-e^+) - pairs, the "flickering mode" becomes equivalent to the action of an electrostatic field, promoting the convergence of nuclei. In addition, as the process of "exchange" of nuclei ($e^- e^+$) - pairs comes closer, more and more compact and more massive ($e^- e^+$) - pairs are included up to the state of π^0 – meson.

Conclusion

The above considerations demonstrate how, already at distances of the order of 100 fm, interaction with the physical vacuum (PV) can occur, promoting the approach of nuclei. As noted in [4], during nuclear fusion one should expect that the PV is in an excited state and has an energy density comparable to nuclear energy. This means that the frequency and energy of PV oscillations, which include the appearance of (e-e+) pairs, are high.

It is possible that when nuclei approach each other at distances $d \leq 10^{-14}$ m, according to a similar scenario, an electromagnetic contribution to the attraction of nuclei occurs due to ($\pi^+ \pi^-$) - pairs when the π^- - meson is localized in the central region of the CC activator.

It is interesting to note that an interpretation of the complete reduction of short-range strong interaction to electromagnetic interaction is also proposed [7].

It is obvious that if there is a sufficient number of (ee) - pairs in the composition of the CC activator, the process of bringing nuclei closer to distances 2d, significantly smaller than R_S^*, becomes real. Therefore, there is no need to focus on achieving R_S^*. as a prerequisite for starting the second stage of nuclear fusion. This, in turn, ensures the start of strong nuclear interaction, removing the question of overcoming the Coulomb barrier.

References

1. M. Kashchenko and N. Kashchenko, Low-temperature Nuclear Fusion: an Introduction to the Problem and its Conceptual Solution, 180 p. (2022).

2. M. Kashchenko and N. Kashchenko, The Role of the Electronic Current Component in the Formation of a Quasi-Molecular State Leading to the Synthesis of Elements, Letters on Materials **10,** No 3, 266 (2020). DOI: 10.22226/2410-3535-2020-3-266-271

3. Kashchenko M. P., Kashchenko, N. M. (2022). «Development of a model of a quasi- molecular state for low-temperature synthesis of nuclei and interpretation of the formation of chemical elements in the process of vacuum melting of a metal by an electron beam». // In V. L. Derbov (Ed.), *Saratov Fall Meeting 2021: Laser Physics, Photonic Technologies, and Molecular Modeling* [121930V] (Progress in Biomedical Optics and Imaging - Proceedings of SPIE; Vol. 12193). SPIE. https://doi.org/10.1117/12.2626913

4. Kashchenko M. P., Kashchenko, N. M. (2023). Energy density of the physical vacuum and estimation of the mass of a compact electron (ee) – pair. Preprint. https://www.researchgate.net/publication/373650897. DOI: 10.13140/RG.2.2.30521.54880

5. Santilli R.M. Foundations of Hadronic Chemistry. With Applications to New Clean Energies and Fuels. Boston-Dordrecht-London: Kluwer Academic Publishers; 2001. 554 p.

6. H. Yukawa. On the Interaction of Elementary Particles I// Proc. Phys. Math. Soc. Japan. 17(2), 48-57 (1935). DOI: 10.1143/PTPS.1.1

7. Jean Louis Van Belle (2021). Do we need the nuclear force hypothesis? Preprint. https://www.researchgate.net/publication/350872167. DOI: 10.13140/RG.2.2.13315.43042/6